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EFFECT OF CROP RESIDUE AND NUTRIENT COMBINATION ON SOIL SULPHUR DYNAMICS AT DIFFERENT STAGES OF CROP GROWTH UNDER MAIZE-WHEAT CROPPING SYSTEM

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ABSTRACT

India being an agriculture-dominant country produces more than 500 million tons of crop residues annually. Farmers in India burn or remove residues to facilitate seedbed preparation. Burning of crop residues is common in India causing nutrient losses (like N, P, K and S) and serious air pollutions affecting human health. To avoid straw burning, innovations in crop residue management should assist in achieving sustainable productivity and allow farmers to reduce nutrient and water inputs, and reduce risk due to climate change. Crop residues contain significant quantities of plant nutrients and their judicious application will have positive effect on nutrient management in maize-wheat system. The objective of this study was to investigate the effects of addition of crop residue and different inorganic nutrient combination on soil available sulphur, their concentration and uptake at different stages of crop growth. The available sulphur content of soil at three different stages of maize and wheat at 0-15 cm depth varied from 25.6-123.6 kg/ha and 21.3-90.6 kg/ha, and 13.7-80.7 kg/ha and 15.5-85.0 kg/ha with and without incorporation of crop residues respectively. S concentration in maize plant ranged between 0.04-0.72% and 0.09-0.52%, while in wheat plant ranged from 0.12-0.93% and 0.10-0.42% with and without incorporation of crop residues respectively. S uptake by the maize grain, straw and total S uptake by maize varied from 0.32 to 2.22 kg/ha and 0.15 to 2.57 kg/ha, 2.79 to 12.09 kg/ha and 0.79 to 12.10 kg/ha and 3.11 to 14.21 kg/ha and 0.94 to 13.88 kg/ha with and without incorporation of crop residues respectively, while in wheat crop S uptake by the grain, straw and total S uptake of the wheat crop, with and without incorporation of maize residue was varied from 0.50 to 2.70 kg/ha and 0.38 to 2.55 kg/ha, 5.98 to 28.97 kg/ha and 5.69 to 24.52 kg/ha and 6.48 to 30.87 kg/ha and 6.07 to 26.92 kg/ha respectively.

KEYWORDS: Crop Residues, Maize (Zea Mays L.), Inorganic Fertilizer, Nutrient Omission & Wheat (Triticumaestivum L.).

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Original Article

INTRODUCTION

Crop residues are part of the plants left in the field after crops have been harvested and thrashed. Indian agriculture produces about 500-550 million tonnes (Mt) of crop residues annually. There is production of 93.9 million tons (Mt) of wheat, 104.6 Mt of rice, 21.6 Mt of maize, 20.7 Mt of millets, 357.7 Mt of sugarcane, 8.1 Mt of fibre crops (jute, mesta, cotton), 17.2 Mt of pulses and 30.0 Mt of oilseeds crops, in the year 2011-12 (MoA 2012). This huge volume of crop residues is produced both on-farm and off-farm. These crop residues are used as animal feed, soil mulch, manure, thatching for rural homes and fuel for domestic and industrial purposes and thus are of tremendous value to farmers. However, a large portion of these crop residues, about 90-140 Mt annually, is

burnt on-farm primarily to clear the fields to facilitate planting of succeeding crops. The problem of on-farm burning of crop residues has intensified in recent years due to use of combines for harvesting and high cost of labours in removing the crop residues by conventional methods. Crop residue retention is a key component of sustainable cropping systems. In recent years, retention of crop residue is a means of improving soil quality and nutrient capacity and reducing the adverse effects of residue burning. The continued use of chemical fertilizers leads to a continued decline in soil quality and other environmental problems. For example, the application of nitrogen (N) fertilizers is proven to cause low N use efficiency (NUE) in crops and environmental pollution by the accumulation of NO_3–N in the soil (Zhao and Chen 2008). Crop residues are an important source of plant nutrients and organic matter. Long-term residue retention increases soil microbial composition and biomass, promotes soil nutrient recycling, increases the soil organic matter (SOM) content (Liu *et al*. 2011), improves soil quality, creates a soil regime favorable for root development, and results in higher crop yields (Zhao and Chen 2008). The retention of crop residues has been proven as an effective field practice in terms of reducing nutrient inputs (Ma *et al.* 2003), especially in rain-fed conditions. However, the removal of crop residues from the field is known to hasten the decline in soil organic carbon (SOC), especially when coupled with conventional tillage (Abro*et al.* 2011). Therefore, residue retention should be strongly recommended in crop production (Wu *et al.* 2002). The recycling of crop residues has the advantage of converting the surplus farm waste into useful product for meeting nutrient requirement of succeeding crops. Crop residues are a source of organic C for soil microorganisms and also contribute to plant nutrients. Maize–wheat rotation is a major double-cropping system practiced on more than one fifth of agricultural lands worldwide. Currently, more than 50 % of maize residues are retained immediately after harvesting. Most farmers remove maize straw for feeding the animals. However, management of the wheat straw is a major challenge as it is considered to be a poor feed for the animals owing to a high silica content.

Unlike removal or burning of crop residue, incorporation of straw increases soil organic matter and N, P and K contents in soil. Ploughing is the most efficient residue incorporation method (Christian and Bacon 1991). Crop residues may be incorporated partially or completely into the soil depending upon methods of cultivation (Dormaar and Carefoot 1996).

Incorporation of maize residues before wheat planting compared to incorporation of wheat straw before maize planting is difficult due to low temperatures and the short interval between maize harvest and wheat planting. The incorporation of Crop Residues in the field is beneficial in recycling nutrients, but leads to temporary immobilization of nutrients (e.g., Nitrogen) and extra nitrogenous fertilizer needs to be added to correct the high C:N ratio at the time of residue incorporation (Singh *et al.* 2008). This N deficiency caused by decomposed microbial immobilization of available soil and fertilizer nitrogen in the short term. However, this can be reduced with the incorporation of nitrogen as starter dose along with straw incorporation (Mandal *et al.*, 2004).This paper summarizes state-of-knowledge on the effects of nutrients and residue management practices on Sulphur dynamics in maize-wheat based cropping systems in Jharkhand. Among cereals, maize (*Zea mays*), is an important crop which ranks third after wheat and rice in the world (Rasheed *et al*., 2004). It is cultivated with different crop sequence under various agro climatic regions of the country. Hence, it is considered as potential driver of crop diversification under different situations (Jat*et al.*, 2011). Wheat is the most important cereal crop of the world. It is the staple food of different countries of the world. With the existing rice-wheat system there isemerging challenges of natural resource-based degradation, declining crop productivity and ecological problems, the maize based cropping systems are emerging as an alternative option for diversification of rice-wheat and rice-rice production systems. Amongdifferent maizebased cropping systems, maize-wheat cropping system ranks first (Jat*et al.*, 2011). However, proper

combination of both organic and inorganic fertilizers have better effects on crop growth and development and yield component of crop than alone (Manna *et al.,* 2005), due to excess and imbalanced use of nutrients and continuous nutrient mining from the soil deteriorated crop productivity and ultimately soil health.

MATERIALS AND METHODS

The experiment was conducted during the year (2016-17) in Research Farm area of Ranchi Agriculture College, Birsa Agricultural University, which comes under western plateau region (Subzone VI) situated at $23^{0}19^{/}$ north and $83^{0}17^{/}$ east with an altitude of 625 meter above mean sea level. The climate of experimental site is tropical with hot wet summers and mild winters. Temperature can soar upto 42^{0} C in summer. The monsoon season is July to September and the state receives an annual rainfall of 1456.6 mm. Each plot was divided into two equal parts before sowing of crops. In one part, straw (maize/wheat) (which was obtained from that plot during last crop) was incorporated along with chemical fertilizer as per treatment and in another part, only chemical fertilizers was applied. Altogether there were comprising five treatments with and without crop residues incorporation, replicated four times in a Randomized Block Design (RBD) to give a total of 40 experimental units. The experiment consisted of five treatments including: T_1 - ample NPK (250: 120: 120 kg/ha), T_2 - omission of N with full P and K (-N = 0: 120: 120 NPK kg/ha), T_3 - omission of P with full N and K (-P = 250: 0: 120 NPK kg/ha), T_4 - omission of K with full N and P (-K = 250: 120: 0 NPK kg/ha) & T_5 - SSNM (200: 90: 100 NPK kg/ha) for maize in kharif season. The corresponding treatments for wheat in rabi season were (T_1= NPK) 150: 110: 100 kg/ha, (T_2 = -N) 0: 110: 100 NPK kg/ha, (T_3 = -P) 150: 0: 100 NPK kg/ha, (T_4 = -K) 150: 110: 0 NPK kg/ha and (T_5 = SSNM) 120: 70: 60 NPK kg/ha. The recommended fertilizer dose for maize crop was treated as NPK (250:120:120) and SSNM (200:90:100), while wheat was shown in the same plots of Kharif with different dose of NPK (150:110:100) and SSNM (120:70:60). The widespread use of high-analysis, granular S-free NP fertilizers such as urea, mono-ammonium phosphate (MAP), diammonium phosphate (DAP) and triple superphosphate (TSP), together with more intensified cropping with higher yields, has resulted in increasing occurrences of soil S-deficiency in many countries (Chien*et al*., 2009). The sources of N, P, and K were urea, single super phosphate and muriate of potash, respectively. The fertilizer single superphosphate which contains and supply 12% S in addition to 16% P_2O_5 to the experimental crops. The application of nitrogen and potash in maize crop was applied as a base and V_4 stage in two splits while in wheat was also completed in two splits (50% basal + 50% CRI stage) as per the treatments. The maize hybrid used was Pioneer- 3377 with a planting geometry of 70 x 18 cm^2 and the wheat variety was DWB- 17 with a spacing of 30 x 10 cm^2. Soil samples from the plots of each treatments and replication were collected at depth 0-15 cm. The soil samples were collected at different stages i.e. at V_4 stage, V_{10} stage and after harvest of the maize crop (during maize crop season) and at CRI (Crown root initiation), PI (Panicle initiation) and after harvest of wheat (during wheat Crop season). Soil samples were ground on a wooden plank with wooden roller. The soil samples were mixed thoroughly and were passed through 80 mesh sieve and stored in cellophane bags with appropriate levels in a clean and dry place. Plant samples at different growth stages of the maize (V_4, V_{10} and after harvest stages) and wheat (CRI, PI and after harvest stages) crops as per treatment, straw and grain samples at harvest were collected and brought to the laboratory. The plant samples were washed with double distillation water; air dried and kept in brown paper bags with proper tagging. The samples were air dried in hot air oven at 65^{0}C or dried in a dry oven at 60^{0}C for 3-4 days. Oven dried plant samples were ground in steel blade grinder and kept for analysis.

Nutrient availability and their uptake and post-harvest fertility status of soils were noted. The soil of the experimental site was sandy loam. Initial soil available nutrients in each treatment plot of the experimental site were assessed. The experimental soil was sandy loam in texture. The soil samples were analysed by following standard procedure for the soil's available sulphur was extracted by 0.15% $CaCl_2$ solution (William's and Steinberg, 1959). The sulfur content in plant (grain and straw) samples was digested in diced mixture HNO_3: $HClO_4$ (10: 4) and determined using the turbidimetric method of (Chesnin and Yien, 1951).

The S uptake by maize and wheat were computed from their respective nutrient concentration in plant components by using expression:

Nutrient Uptake (kg ha^{-1}) = Nutrient Concentration (%) x Yield (q ha^{-1})

Nutrient Harvest Index (S) of maize and wheat were computed by using expression

$$\text{Nutrient Harvest Index (\%)} = \frac{\text{Nutrient uptake (by grain or straw) in kg ha}^{-1}}{\text{Total uptake (grain uptake + straw uptake) (kg ha}^{-1})} \times 100$$

RESULTS AND DISCUSSIONS

Available S

The data presented in table-1 indicate available sulphur content of soil at three different stages of maize at 0-15 cm depth varied from 25.6-123.6 kg/ha and 21.3-90.6 kg/ha, with and without incorporation of crop residues. Available sulphur content of soil decreased up to stage $V_{10}$and stabilized after harvest of the crop. Available S was minimum in phosphorus omission plots at all the stages. These results are in agreement with the work of Singh *et al* (2009) in red soils of Ranchi. They reported that residues incorporation increased the availability of sulphur. The increase in the available S with the application of fertilizers might be due to the addition of SSP which contained about 12% of S. These results are in conformity with the findings of Sharma and Subehia (2014), addition of wheat straw and green manure contributed an appreciable amount of sulphur i.e. 0.17, 0.06, 0.08%, respectively, adding about 6.0, 3.6 and 1.12 kg ha^{-1} S to the soil at 50% substitution rate which resulted in increased S content of the soil over control. Sarkar *et al.* (1998) also reported that various natural organic sources like compost, FYM and crop residues can supply adequate quantities of S to crop.

Table -1 revealed that available sulphur content of soil at three different stages of wheat i.e. at CRI stage, PI stage and after harvest of wheat crop at 0-15 cm depth ranged from 13.7-80.7 kg/ha (with residues) and 15.5-85.0 kg/ha (without residues). In P omission plots, available P reduced considerably which may be due to the absence of SSP which was applied as the source of P-fertilizer to the crop. At PI stage available sulphur declined from the CRI stage and increased after harvest in residue incorporated plots. Verma*et al.* (2016) also observed similar result that is significant increase in available sulphur content of soils with incorporation of crop residues. Thakur *et al.* (2011) also reports, improvement in soil available S by crop residue incorporation.

S Concentration

The data reported in table- 2 reveal the S concentration in maize plant at different growth stages of maize crop. S concentration in maize plant ranged between 0.04-0.72% (with straw incorporation) and 0.09-0.52% (without straw incorporation) and it decreased from V_4stage (0.23-0.72%) to V_{10} stage (0.08-0.13%). While S concentration in wheat plant at different growth stages ranged from 0.12-0.93% and 0.10-0.42% with and without incorporation of crop residues.

Higher S concentration was recorded in the plants of residue incorporated plots. S concentration was minimum in the plants of P omission plots. At CRI stage, sulphur concentration varied between 0.18-0.40%, which increased at PI stage (0.23-0.93%) and decreased after harvest (0.12-0.22%) in the plants of residue incorporated plots (Table- 2).

S Uptake

S uptake by the maize grain varied from 0.32 to 2.22 kg/ha and 0.15 to 2.57 kg/ha with and without incorporation of crop residues respectively (table-3). S uptake by the grain was minimum in N omitted plot. S uptake by the maize straw (with residue) varied from 2.79 to 12.09 kg/ha whereas S uptake by the straw (without straw) varied from 0.79 to 12.10 kg/ha. Highest value of S uptake was found with the application of NPK among all treatment. Total S uptake by maize (with residue) ranged from 3.11 to 14.21 kg/ha whereas S uptake by the straw (without straw) varied from 0.94 to 13.88 kg/ha. Table-3 presented S uptake by the grain, straw and total S uptake of the wheat crop, with and without incorporation of maize residue. S uptake by the grain (with straw) varied from 0.50 to 2.70 kg/ha whereas S uptake by the grain (without straw) varied from 0.38 to 2.55 kg/ha. Such an increase was due to the application of graded level of S through SSP and secondly due to considerable increase in grain yields (Kumar *et al.* 2011). S uptake by the grain was minimum in N omitted plot. S uptake by the grain with the application of 120:70:60 (SSNM) was significantly higher than all other treatments. S uptake by the straw (with residue) varied from 5.98 to 28.97 kg/ha whereas S uptake by the straw (without straw) varied from 5.69 to 24.52 kg/ha. S uptake by the straw increased with the residue incorporation in nutrient omitted plots in comparison to without incorporation of crop residues. Total S uptake by the wheat varied from 6.48 to 30.87 kg/ha and 6.07 to 26.92 kg/ha with and without incorporation of crop residues respectively. Increasing trend was recorded with incorporation of crop residues in comparison to without residues. The similar result was studied by Pandey *et al.* (2016).

Sulphur Harvest Index (SHI)

The nutrient harvest index (NHI) is usually used as a parameter for evaluating nutrient utilization efficiency. It represents a percentage of grain nutrient in total plant nutrient. The critical perusal of data presented in table -4 explain that crop residue incorporation enhanced sulphur harvest index in nutrient omission plots. In maize crop the S harvest index varied from 0.10-0.17 per cent (with residue) and 0.13-0.32 per cent (without residue). The mean increase in S harvest index in residue incorporated N, P & K omission plots was found 69.77, 35.26 & 45.03 per cent respectively than that of without residue N, P & K omission plots. While in wheat crop the SHI varied from 0.06-0.10 and 0.06-0.12 with and without residue incorporated plots respectively. The data explicit that crop residue incorporation had increase in S harvest index was observed after incorporation of crop residues. The harvest index (SHI) was higher with residue incorporation than without residue. Similar effect was also reported by Wei *et al.* (2015) based on a four –year field experiment.

CONCLUSIONS

It is concluded that application of nutrients with previous crop straw in long-term was found best among all the treatments with ample NPK application. Average S content was low at stage V_4 and further increased at stage V_{10} and stabilized after harvest of the maize crop at 0-15cm depth. In wheat plots with crop residues average S content increased at PI stage. Maximum S uptake were found with the application of NPK under maize-wheat cropping system with incorporation of crop residue. With the incorporation of crop residues the nutrient internal use efficiency increased by 3% in wheat crop.

Finally, it is concluded from the present study that nutrient dynamics in the maize-wheat sequence in Alfisol of Ranchi, with and without residue incorporation has no definite pattern of availability of nutrients in soil and plants at different stages of crop growth. However, maximum nutrient concentrations were observed at V_4 and CRI stages in plants. Also, the higher concentration of nutrients in soil was associated at the same stages.

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APPENDICES

Table 1: Effect of Straw Incorporation and Nutrient Use on Available S (kg/ha) at Different Stages of Maize and Wheat

Treatments	Maize						Treatments	Wheat					
	Stage V_4		Stage V_{10}		After harvest			Stage CRI		Stage PI		After harvest	
	With straw	With out straw	With straw	With out straw	With straw	With out straw		With straw	With out straw	With straw	With out straw	With straw	With out straw
NPK (250:120:120	73.6	49.9	57.9	46.50	80.9	67.9	NPK (150:110;100	65.7	27.7	24.0	28.4	80.7	69.7
(-N)	67.6	67.7	49.2	55.91	123.6	90.6	(-N)	73.3	55.0	61.2	56.1	74.2	85.0
(-P)	25.6	21.3	31.0	26.95	34.0	24.8	(-P)	13.7	18.7	18.7	15.5	46.0	42.1
(-K)	54.6	63.6	46.5	34.37	75.1	74.5	(-K)	37.2	54.2	31.9	31.2	79.2	68.4
SSNM (200:90:100)	52.7	79.1	46.5	25.59	71.5	73.2	SSNM (120:70:60)	46.7	27.4	40.4	37.2	64.0	66.9
CD@5%	8.9	12.5	20.1	17.05	8.8	11.8	CD@5%	13.6	9.9	10.7	4.6	18.4	15.8
CV%	10.5	14.4	28.2	29.23	7.4	11.5	CV%	18.7	15.8	19.7	8.9	17.3	15.4

Table 2: Effect of Straw Incorporation and Nutrient Use on S Concentration (%) at Different Stages of Maize and Wheat Plants

Treatments	Maize						Treatments	Wheat					
	Stage V_4		Stage V_{10}		After harvest			Stage CRI		Stage PI		After harvest	
	With straw	With out straw	With straw	With out straw	With straw	With out straw		With straw	With out straw	With straw	With out straw	With straw	With out straw
NPK (250:120:120	0.25	0.19	0.13	0.11	0.10	0.12	NPK (150:110;100	0.30	0.28	0.81	0.42	0.22	0.21
(-N)	0.23	0.35	0.08	0.09	0.07	0.11	(-N)	0.22	0.19	0.29	0.27	0.21	0.20
(-P)	0.72	0.43	0.11	0.11	0.06	0.12	(-P)	0.18	0.16	0.23	0.20	0.18	0.12
(-K)	0.66	0.48	0.09	0.12	0.04	0.10	(-K)	0.36	0.33	0.38	0.32	0.12	0.10
SSNM (200:90:100)	0.50	0.52	0.09	0.13	0.06	0.13	SSNM (120:70:60)	0.40	0.35	0.93	0.36	0.15	0.12
CD@5%	0.14	0.06	37.00	32.37	0.01	0.03	CD@5%	0.03	0.04	0.07	0.03	0.04	0.03
CV%	19.62	9.94	16.56	16.56	11.96	15.68	CV%	7.20	9.66	7.51	5.68	14.64	12.11

Table 3: Effect of Straw Incorporation and Nutrient Use on S Uptake (kg/ha) of Maize and Wheat

Treatments	Maize						Treatments	Wheat					
	Grain S uptake		Straw S uptake		Total S uptake			Grain S uptake		Straw S uptake		Total S uptake	
	With straw	With out straw	With straw	With out straw	With straw	With out straw		With straw	With out straw	With straw	With out straw	With straw	With out straw
NPK (250:120:120	2.22	1.78	11.01	12.10	13.23	13.88	NPK (150:110;100	2.3	2.28	27.45	18.68	29.75	20.96
(-N)	0.32	0.15	2.79	0.79	3.11	0.94	(-N)	0.5	0.38	5.98	5.69	6.48	6.07
(-P)	1.24	2.57	11.07	5.40	12.31	7.97	(-P)	1.4	1.03	14.11	7.41	15.51	8.44
(-K)	1.01	0.99	6.14	2.94	7.15	3.93	(-K)	1.9	2.17	28.97	24.52	30.87	26.92
SSNM (200:90:100)	2.12	2.18	12.09	5.79	14.21	7.97	SSNM (120:70:60)	2.7	2.55	23.48	23.91	26.18	26.46
CD@5%	0.41	0.31	1.62	1.35	1.52	1.37	CD@5%	0.2	0.3	5.27	6.31	5.34	6.36
CV%	19.03	12.93	12.18	16.25	9.84	12.78	CV%	9.2	10.5	17.13	25.44	15.95	23.21

Table 4: Effect of Straw Incorporation and Nutrient Use on Nutrient Harvest Index of Maize and Wheat Crop

Treatments	S HI Maize		Treatments	S HI Wheat	
	With Straw	Without Straw		With Straw	Without Straw
NPK(250:120:120)	0.17	0.13	NPK(150:110;100)	0.08	0.11
-N	0.10	0.16	-N	0.08	0.06
-P	0.10	0.32	-P	0.09	0.12
-K	0.14	0.25	-K	0.06	0.08
SSNM(200:90:100)	0.15	0.27	SSNM(120:70:60)	0.10	0.10